THE

FUNCTIONS OF THE BRAIN

BY

JULIUS ALTHAUS, M.D.

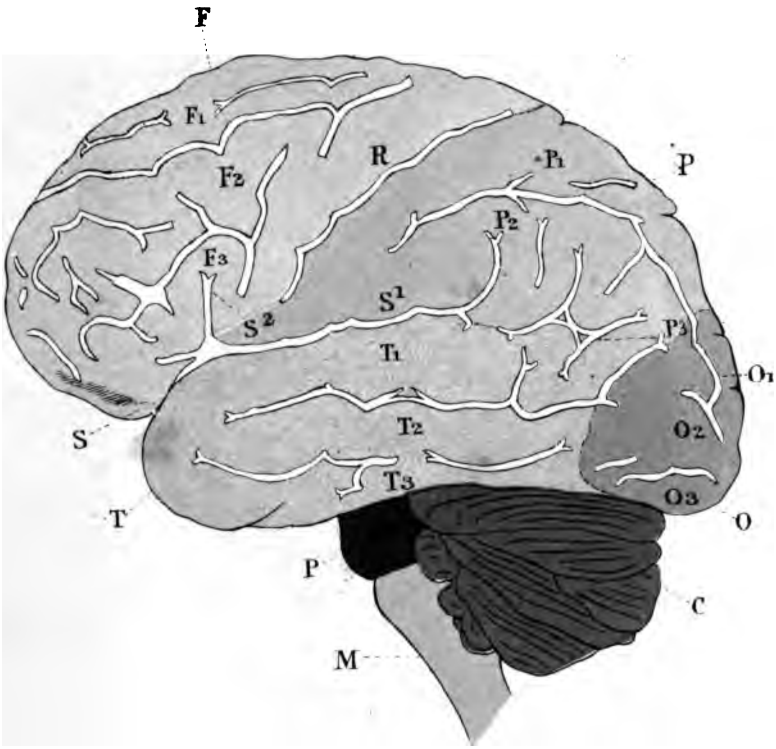

FIG. 4.

Lateral view of the brain.

M—Medulla.

P—Pons. C—Cerebellum.

F—Frontal or anterior lobe of the brain; seat of the intellect. F^1 F^2 F^3—First, second, and third frontal convolution.

R—Fissure of Rolando, dividing the frontal from the parietal lobe.

S S^1 S^2—Fissure of Sylvius. S^1—Horizontal branch of it, dividing the parietal from the temporal lobe. S^2—Ascending branch of it, separating the frontal from the temporal lobe.

P—Parietal lobe, constituting the motor area of the hemispheres, or the psycho-motor centres. P^1 P^2 P^3—First, second, and third parietal convolutions.

T—Temporal lobe; seat of conscious sensations and perceptions; centre for the organs of sight, smell, hearing, taste, and touch. T^1 T^2 T^3—First, second, and third temporal convolutions.

O—Occipital lobe; seat of the animal propensities. O^1 O^2 O^3—First, second, *and third occipital convolutions.*

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THE

FUNCTIONS OF THE BRAIN;

A POPULAR ESSAY.

BY

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PREFACE.

Some months ago I delivered a Lecture on the Functions of the Brain, to a lay audience—the Members of the German Athenæum in London; and, at the request of several Members of that Society, I now publish the Lecture, with such slight alterations and additions as appeared to me appropriate.

36, Bryanston Street,
Marble Arch,
October, 1879.

THE FUNCTIONS OF THE BRAIN.

At no previous time in the history of Physiology and Medicine has the study of the structure and functions of the brain proved to be of such surpassing interest, or engaged so many able workers, as at present; and as an era in the investigation of these problems has recently closed, it may appear appropriate to point out the ways and bye-ways along which we have travelled to reach our present position; to show the impediments which have marred observation in the course of time; and to trace the gradual development of those more accurate methods of research which are now-a-days employed.

We are inclined to look for the dawn of all knowledge in those nations which first arrived at a certain degree of civilisation; yet we fail to trace any germs of brain-doctrine amongst the old Indians and Egyptians. The dreamy, imaginative Hindoos

felt no temptation to unravel Nature's secrets by a laborious and repulsive dissection of viscera; while the Egyptians, whose minds were habitually clouded by gloomy forebodings, were inclined to look upon the natural forces as phantoms, which inspired them with awe. It is true that they incised the dead body for the purpose of embalming it; but this did not lead to any anatomical or physiological researches, and only produced the mummy, an image of petrified life, well representing the general character of the people with whom it has always been identified. It was only in ancient Greece, where the natural development of mental culture proceeded, unfettered by external or internal restraint, that men began to study form and shape as well as vital function, and endeavoured to recognise the intimate and mysterious union existing betwixt the two. Free speculation preceded sober experience, and the first period in the history of brain-knowledge is therefore marked by general doctrines of the leading philosophers.

Plato, in "Timæus," affirms the brain to be the seat of the mind, the divine and ruling power within us; the gods have therefore modelled it in accordance with the configuration of the world, and given it the globular, as the most perfect form. In order that the divine in man may not be unduly disturbed by what is mortal, the neck is formed to

separate the head from the body, where the mortal soul, with all its passions and desires, finds its working place. Aristotle, on the other hand, declares the origin of sensation, as well as of life itself, to be in the heart, this being the organ first formed in the embryo. Its activity is perceptible under emotion, and injury to it is fatal. According to him, the brain is the direct opposite to the heart: it is insensible to touch; it causes sleep, for only animals provided with a brain are capable of sleeping; and it is intended to regulate the heat of the heart and to cool the blood.

Hippocrates, the great physician, chiefly studied the brain in so far as it might become of importance to the medical practitioner. He stated injuries to the crown of the head to be the most serious, as being particularly liable, from the fragility of the parietal bones, to cause damage to the organ. This latter may be, according to him, too warm or too cold, unduly dry or moist. If heated by bile, raving madness will ensue; if chilled by phlegm, melancholia is the result. The brain also serves for the excretion of impurities, which escape through the eyes, nose, ears, palate, and throat. If these channels be obstructed, epilepsy is apt to follow; and where the excretion is unduly increased, catarrh will be caused.

When Macedon vanquished Greece, and Rome

laid Macedon low, the passion for speculation and the pursuit of science was extinguished. The natural philosophy of the Greeks, which had only just commenced to flourish, was embalmed in the libraries of Alexandria, and was afterwards transferred to Rome, where, however, it remained an exotic, and was only scantily appreciated by the mistress of the world. The sum total of previous knowledge is found expressed in the writings of Galen, which authoritatively determined the direction of science for many centuries. He stated the brain to be the seat of thought and action, and believed its structure to be identical in the lower animals and man. He thought it was composed of two halves, in order that one side might still continue to act after injury to the other.

For more than a thousand years after Galen no progress whatever was made in the physiology of the brain. Mankind appeared to be seized by a kind of fever, which was only much later recognised as an evolutional disease. Science could not flourish where barbarians ruled, where blind superstition overawed the people, and the yoke of princes led to unquestioning submission to authorities. Plato's sparkling doctrine was therefore caricatured into Neo-platonic obscurantism, and the Aristotelian method tortured into scholastic absurdities.

When the Arabs, led by Mohammed, reached the

highest pinnacle of their political power, they received with deference European learning, the monuments of which they had conquered in Egypt and Greece; yet neither anatomy nor physiology could thrive amongst the followers of Islam, for religious precepts prohibited them from dissecting; and the singular mixture of enthusiasm and inertia which was the distinctive feature of their character, was unfavourable to scientific pursuits.

At last the inherent power of the European races overcame the tedious illness which had prostrated them so long. The struggle against the supremacy of the Church of Rome and literary authorities; the renewed study of Greek classics; the voyages of discovery, and the progress in the useful arts, were all so many symptoms of a fresh trial of mental strength. The era of the *renaissance* began in Upper Italy, where the emulation of the smaller States, the republican spirit in them, as well as the support given by liberal-minded princes, electrified the minds; and Bologna, Padua, and Pisa became the high schools of anatomy for the whole of Europe.

The crisis in anatomy was brought about by Vesalius (1542), whose passion for research was such as to subject him to great inconvenience and danger, when attempting to procure bodies for dissection. At that time it was thought blasphemous

to mutilate human remains, and physicians and surgeons derived their anatomical knowledge from the dissection of dogs and monkeys. Vesalius was only twenty-eight years of age when he published his great work "De Corporis Humani Fabricâ," which gave an entirely new base to anatomy, and, according to the saying of his contemporaries, laid a new world bare. He was the first to distinguish the white and grey matter of the brain, and described its general configuration more accurately. His teaching created the greatest excitement in the Italian centres of learning, and his merit was appreciated by Charles V. and Philip of Spain, to whom he acted as physician; yet his brilliant career was cut short by the Inquisition, and he was drowned on returning from a pilgrimage to Jerusalem, which had been forced upon him. His work stirred up a host of eager successors, amongst whom Varoli of Bologna was one of the most illustrious. He first described that portion of the brain which is now known as the "Pons Varolii," and examined carefully the base of the brain. Although not persecuted like Vesalius, he had to suffer throughout his career from the meanness and envy of ill-natured detractors.

The next great name in this branch of science is Willis, of Oxford (1664), who dissected more neatly than his predecessors, and first injected coloured

liquids into the blood-vessels, so as to show their ramifications in the cerebral substance. He also began to make use of the data furnished by comparative and pathological anatomy on this point; published drawings of the different portions of the brain of which he discovered several important parts which had previously been overlooked; and described the nine pairs of nerves which arise from the base of the brain, and send power to the organs of special sense, as well as impart motion and sensation to the face and head. Malpighi (1661), who taught in Pisa, Bologna, and Messina, first used the microscope for ascertaining the more intimate structure of the brain, and found the white matter to consist of delicate tubes or fibres.

The Dutch, who owed liberty, wealth, and the very soil on which they lived to their extraordinary working powers had, at that period, raised their country to the first rank amongst nations, and undertook chiefly such investigations as require ceaseless industry and application, and where the smallness of the objects examined appeared to put insuperable obstacles in the way of enquirers. With the aid of the microscope they discovered hitherto unknown structures, and prepared specimens which are even now worthy of admiration. Swammerdam first described the middle tunic or arachnoid membrane of the brain; and Leuwenhoek showed the grey matter

to consist of very fine globules. Ruysch perfected the art of injecting the blood-vessels with coloured liquids, and of preserving specimens. He hardened the brain in a kind of balsam which he invented and kept secret, and furnished preparations which are now in a state of perfect preservation.

About the same period France entered the lists, and Louis XIV., desirous to add to the brilliancy of his reign, gave ample support to scientific institutions, such as the Paris Academy of Sciences; yet surgery was more successfully cultivated by the French than anatomy. In the commencement of the eighteenth century, however, François Petit made several important discoveries in the anatomy of the brain, showing, for instance, the crossing of the motor nerve-fibres in that portion where the spinal cord joins the brain—a fact which explains why disease in one half of the brain should cause paralysis in the opposite side of the body.

The Germans manifested at that time more industry in collecting facts discovered by others than original research; and the first truly great Teutonic name in this science is Albrecht von Haller (1762), who brought all previously acquired knowledge into one common focus, compared the brain of birds and fishes with that of man, and gave a fresh impetus to physiological enquiry. Soemmering and Prochaska followed in his footsteps; while Gall, in the com-

mencement of the present century, added more largely to our knowledge, and greatly improved the methods of examination. Instead of simply cutting up the structures, he steadily pursued the course and connexions of the fibres, and was thus led to a number of discoveries regarding this important point. He was less fortunate in erecting the unstable edifice of phrenology, for he completely failed in proving his chief point, viz., that external bumps on the skull corresponded to equivalent portions of the brain's surface. Reil, of Halle, undaunted by the persecution of the first Napoleon, who suppressed that university, followed the better way of careful dissection. Carus, of Dresden, traced the gradual evolution of the brain in the animal kingdom from its lowest beginnings. Tiedemann, of Heidelberg, investigated the development of the organ through every month of human embryonic existence; and Stilling, Meynert and Lockhart Clarke called in the aid of chemical tests and the highest powers of the microscope, whereby they succeeded in giving us a tolerably clear insight into that most complex subject—the origin and ramification of the different *nuclei* and fibres. Experimental physiologists began likewise, within the last few *decennia*, by the aid of the most unjustly abused method of vivisection, to study the functions of individual portions of the brain; and Flourens was the first to

remove certain portions of the organ in pigeons, and to observe the behaviour of the animals after operation.

Faraday's discoveries in electricity had now placed a most convenient stimulant of nervous power—the induced or electro-magnetic current—at the disposal of experimenters; and this was largely, and with the most wonderful results, used by Magendie, Claude-Bernard, and Ludwig, chiefly for investigating the functions of the nerves arising from the base of the brain, as well as of the sympathetic system. But the most important step in modern research, and which may be said to have closed one period of enquiry, and ushered in a new era in our knowledge of brain-function, was the application of electricity to the hemispheres of the brain of living animals, and the observation of the effects caused by such stimulation. The first successful experiments of this kind were made by two German observers, Fritsche and Hitzig, of Berlin, who were soon followed by Ferrier in this country. A secure base was thus given to one of the most important doctrines of the present day, viz., the localization of the cerebral faculties; and if vivisection had done nothing else for science, it would simply on account of this possess a claim on our gratitude. But vivisection is only one of the means which have been employed towards the elucidation of this subject. The clinical features of the several diseases of the

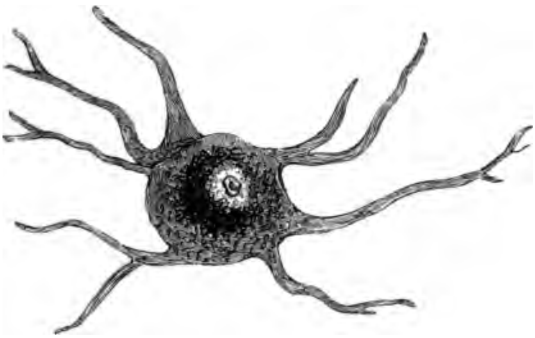

FIG. 1.

Ganglion-cell from the human brain, with nerve-fibres proceeding from it in various directions.

brain have been more attentively studied by hospital physicians, and the symptoms observed during life compared with the results of post-mortem examinations; and thus, by simultaneously bringing anatomy, experimental physiology, clinical medicine, and pathology, to bear upon this great question, the present doctrine of brain-function eventually became established.

I now proceed to give a rapid survey of the fundamental facts of this doctrine.

The brain consists of two different but closely interwoven substances, which, on account of their colour, have been termed the grey and the white matter. The grey matter, which consists of minute cells or globules, is intended to produce and accumulate the nervous force; while the white matter, which consists of tubes or fibres, serves to conduct it in all directions (Fig. 1). The grey matter may therefore be appropriately likened to a galvanic battery in which an electric current is generated, and the white matter to telegraph wires which conduct the current to any place where it may be required. The cells and fibres are cemented together by a kind of connective tissue, which is termed neuroglia, and imparts to them proper support and firmness; the chief structural elements of the brain being therefore cells, fibres, and connective tissue.

The weight of the adult human brain averages

from 40 to 50 ounces, the female brain being generally five ounces lighter than the male. This, however, cannot of itself be considered a proof of the mental superiority of men over women; for in the first instance it has not yet been shown that the proportion of the brain to the entire weight of the body is less in women than in men; and secondly, it is now well known that only one portion of the brain, viz., the anterior or frontal lobes of the hemispheres are the organic base of the intellect. Anatomically speaking, it would therefore be necessary to show, from a considerable number of well-observed cases, that the relative weight of the anterior lobes of the hemispheres is less in women than in men, before we can concede to men a physical advantage over women as far as brain power is concerned.

There can, however, be no question that the weight of the brain is proportionate to the intellectual powers of the individual. Great men have always been found to have had very heavy brains; one of the heaviest on record was Cuvier's, which weighed 64 ounces. The brains of idiots and imbeciles are habitually light, and have been known to weigh as little as 16 ounces. That of the adult gorilla weighs about 15; the horse's 14 to 17, the donkey's 10 to 12 ounces; and the elephant's from 9 to 10 pounds. The elephantine is therefore the heaviest of all;

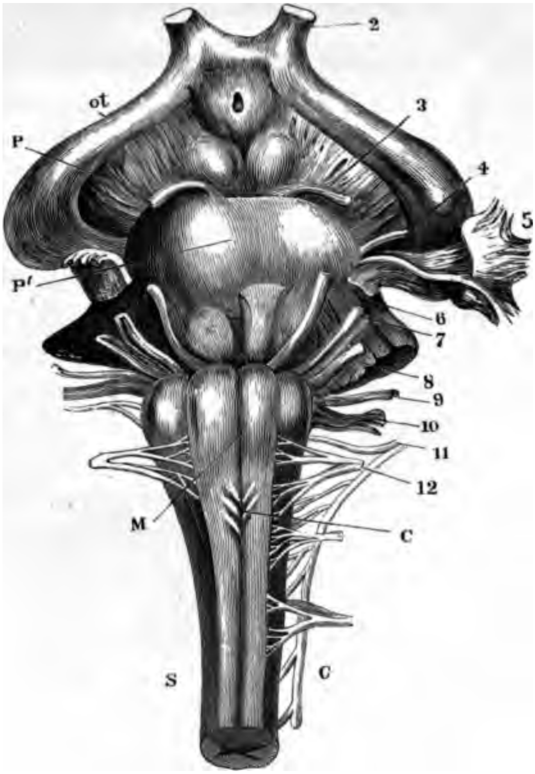

FIG. 2

Upper portion of the spinal cord, medulla, and base of the brain.

S C -Spinal cord, with nerves emerging from its side.
C —Crossing of the fibres in the medulla.
M —Medulla.
P' —Pons.
P —Peduncles of the brain
2 --Optic nerve.
o t —Optic tracts.
3, 4, and 6.—Nerves supplying the muscles of the eye, eyelid, and iris.
5.—Nerve conferring sensibility on the face, taste on the anterior part of the tongue, and motive power on the muscles of mastication.
7.—Nerve supplying the facial muscles.
8.—Auditory nerve.
9.—Nerve conferring taste on the posterior part of the tongue, and sensibility on the throat.
10.—Pneumogastric nerve for the throat, windpipe, lungs, heart, and stomach.
11.—Nerve for the muscles moving the head.
12.—Nerve for the articulation of the tongue.

nevertheless, its relative weight is very much less than that of the human brain; for if we assume the average weight of an adult to be 160 pounds, and that of the elephant 5,000, the proportion of the brain to the weight of the body would be as one to fifty in man, while in the elephant it would be only as one to five hundred.

We may subdivide the brain into five principal parts, the structure and configuration of which are peculiar, and which, although they are all in the most intimate connection with each other, yet are invested with thoroughly different functions. They stand in the relation of higher and lower centres, the lowest being the medulla, and the highest the grey surface of the hemispheres. They are as follows :—

1st. The *medulla oblongata,* which forms the connecting link between the spinal cord and the brain. The spinal cord (S C, Fig. 2), which is contained in the hollow canal of the spine, consists of two tracts of nervous matter, each of which is subservient to motion and sensation in one half of the body. In proceeding upwards into the brain, these tracts expand in the medulla (M), where they become more highly developed, and form fresh connections.

The medulla is a small cord about an inch long, and weighing no more than two drachms; yet it must be looked upon as the most vital part of the whole

body, for injury to it proves immediately fatal. In the medulla the motor fibres proceeding from the spinal cord to the brain cross over from one side to the other (*c*), so that the left half of the brain is in communication with the right half of the body, and *vice versâ*. *Disease of the left side of the brain will, for this reason, produce paralysis of the right side of the body;* while lesions in the right side of the brain cause paralysis of the left side of the body.

2nd. The *meso-cephale*, or middle portion of the brain, comprises the pons, or bridge, and the optic lobes. Emerging from the medulla, the motor and sensory tracts pass into the pons (P′, Fig. 2), which is an almost square protuberance at the base of the brain, situated immediately above the medulla (M); and derives its name from the circumstance that it connects the two hemispheres of the cerebellum (C. Fig. 3), or little brain, so as to constitute a kind of transverse commissure between them. The pons is not merely a conductor, but also a source of nervous power, as in addition to white fibres it contains special accumulations of grey matter, with which the motor and sensory tracts from the medulla form connections. Beyond the pons, these tracts appear as two peduncles (P, Fig. 2), on the posterior part of which are situated the optic lobes (O L, Fig. 3). These are four small eminences, which are white on the surface and grey in the interior, and

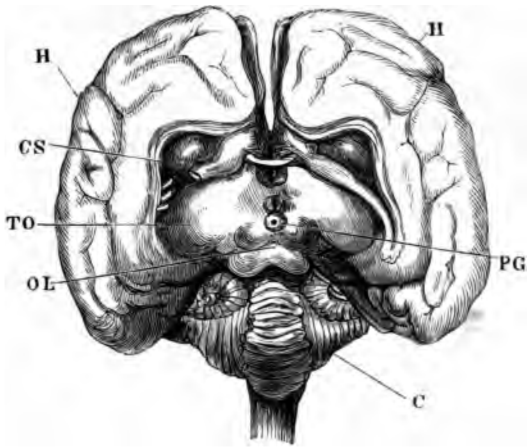

FIG. 3.

Central ganglia in the dog.

H —Hemispheres of the brain.
C S—Corpus striatum } Central ganglia of the brain.
T O—Thalamus opticus }
P G—Pineal gland.
O L—Optic lobes.
C —Cerebellum.

derive their name from giving origin to the optic nerves (2, Fig. 2). On the anterior pair of the optic lobes is situated the pineal gland (P G, Fig. 3), which Descartes and his followers believed to be the seat of the soul.

There are twelve pairs of nerves arising from the base of the brain. The first or olfactory nerve, which is lying in front of the optic, is not represented on Fig. 2; it is appropriated to the sense of smell. The second or optic nerve (2, Fig. 2) is the special nerve of the sense of sight. Both nerves are seen to join at the commissure; and from their origin in the brain up to the commissure they are called optic tracts (*o t*, Fig. 2). The third, fourth, and sixth nerves (3, 4, and 6, Fig. 2) supply motive power to the seven muscles of the eye and eyelid, and also to the iris. The fifth nerve (5, Fig. 2) confers sensibility on the skin and muscles of the face, gives motive power to the muscles of mastication, and imparts taste to a portion of the tongue. The seventh or facial nerve (7, Fig. 2) is distributed to the muscles of the face, to which it conveys their power of motion. The eighth or auditory nerve (8, Fig. 2) is the special nerve of hearing, and is distributed to the internal ear. The ninth or glosso-pharyngeal nerve (9, Fig. 2) is a nerve of taste, and also imparts sensibility to the throat, being chiefly concerned in the act of swallowing. The tenth or

pneumogastric nerve (10, Fig. 2) is distributed to the throat, windpipe, lungs, heart, and stomach. The eleventh or spinal accessory nerve (11, Fig. 2) gives power to the chief muscles moving the head. The twelfth nerve (12, Fig. 2) supplies the muscles of the tongue, and is of great importance for articulate speech.

3rd. The *cerebellum,* or little brain (C, Figs. 3 and 4), consists of two lateral halves or hemispheres and a median lobe, and is by special tracts intimately connected with the medulla, the pons, and the optic lobes. It is situated at the back of the head, beneath the posterior lobes of the brain, and it weighs about five ounces.

4th. The *central ganglia* are connected with the parts beneath them by the peduncles (P, Fig. 2) which pass into them, the sensory tracts proceeding to the optic thalamus (T O, Fig. 3), and the motor tracts into the corpus striatum (C S, Fig. 3) on each side. The *corpus striatum,* or *striated body,* is so called because on dissection it shows a striated appearance, being composed of alternate layers of white and grey matter. Destruction of this part annihilates the power of motion in the opposite side of the body. The second of the central ganglia is called the *optic thalamus,* because it was formerly believed to have some special relation to the sense of sight. Such, however, is not the case, for the optic thalamus has

been shown to be a great centre for common sensation in the body and limbs; and disease or injury of it leads to anæsthesia, or loss of sensation, in the opposite side. These two parts—the striated body and the optic thalamus—lie hidden in the great lateral ventricles or cavities of the brain, and only come into view when the structures above them are removed. They are bathed in a serous fluid, which is called the cerebro-spinal liquor; this is secreted by a delicate membrane investing their surface, and communicates with other cavities in the brain and spinal cord. If there is an excess of this liquid, either from inflammation of the membranes or from wasting of brain-matter, the disease known as hydrocephalus, or water on the brain, is produced.

5th. The *hemispheres*, *convolutions*, or grey surface of the brain, constitute the highest development of nervous matter altogether. They are connected with the parts beneath them by white fibres, which are called the *corona radiata*, and which have the form of a hollow cone. The hemispheres may be subdivided into four different lobes, which are, however, most intimately connected with each other; viz., the anterior or frontal lobes (F, Fig. 4), which are the seat of the intellect; the parietal lobes (P, Fig. 4), which are the seat of conscious voluntary movements; the temporal lobes (T, Fig. 4), which are the seat of conscious sensations and perceptions; and

the occipital or posterior lobes (O, Fig. 4), which are the seat of the animal propensities.

These lobes consist of folds or convolutions, intended to increase their surface; there being three frontal (F^1, F^2, F^3, Fig. 4), three temporal (T^1, T^2, T^3, Fig. 4), three parietal (P^1, P^2, P^3, Fig. 4), and three occipital convolutions (O^1, O^2, O^3, Fig. 4). These convolutions are separated from each other by fissures, the most important of which are the *fissure of Sylvius* (S, S^1, S^2) which divides the frontal and parietal from the temporal lobe, and the *fissure of Rolando* (R), which divides the frontal from the parietal lobe.

I now proceed to consider the functions of all these different portions of the brain consecutively.

1. The *Medulla Oblongata.* The most important function of the medulla is to regulate the respiratory movements; and the point in which this respiratory centre is situated is called the vital knot. Death by hanging results generally from injury to this special point in the medulla, through dislocation or fracture of the upper portion of the spine. The criminal, therefore, dies of asphyxia or cessation of respiration. The entire brain above the medulla may be removed in an animal, and the latter may yet continue to breathe, but destruction of the medulla asphyxiates it at once. The same organ also regulates the heart's action. It is true that the

pulsations of the heart are not, like the respiratory movements, at once arrested by destruction of the medulla, for they may continue for some time after death from hanging. Indeed, the rhythmic beating of the heart is effected by means of small nerve-cells which are situated in the muscular substance, and which may retain their energy for some time after death. The influence of the medulla upon the heart is, therefore, a secondary one, that is, to retard or to accelerate it. The medulla is never at rest as long as life lasts, for respiration, as well as the heart's action, continue during sleep as well as in the waking condition in a typical manner.

The same organ is the centre of action for the blood-vessels, which are not always equally distended, but may be more or less contracted or dilated, as seen in sudden blushing or pallor, under the influence of diverse mental emotions. The insensible perspiration of the skin, which, like respiration, is also going on constantly, is likewise under the influence of the medulla.

A pointed illustration of these facts is given by the symptoms of the peculiar disorder known as sunstroke. This affection occurs more particularly in the tropics, but is occasionally observed in hot weather in the temperate zòne, in persons who are exposed to the direct rays of the sun, and who have at the same time to undergo exertion. It is, there-

fore, chiefly seen in soldiers marching during the heat of the day, or in agricultural labourers working in the fields; yet it has been known to come on at night, in persons sleeping in the pestilential atmosphere of over-crowded and badly ventilated barracks or cabins, and in children who sleep in a stifling room after having been exposed to great heat during the day. It would, therefore, be more appropriate to speak of heat-stroke; for the disorder really consists of a great and sudden rise in the temperature of the blood, which in this state acts as a poison on the medulla. Perspiration is suddenly arrested; and as the evaporation of sweat on the surface of the body is intended to produce cold, and thus to neutralise the effects of external heat, the closure of this safety-valve causes a further rise of temperature, which paralyses some or all of the centres in the medulla. The worst kind of heat-stroke is that in which the centres for respiration and the heart's action are affected, as fatal syncope or asphyxia is the result. A person who may be walking in the streets, or working in a field, is suddenly seen to drop down as if shot or struck by lightning, and dies in a few minutes. A fatal issue is, in such cases, so rapid that there is no chance for any treatment to do good, more especially as the means which would be of the first importance, viz., plenty of cold water and ice, are usually not at once to be had.

The second kind of sunstroke is owing to paralysis of the centre for the blood-vessels, whereby apoplexy is caused. In such instances the symptoms are not quite so sudden, and death may often be averted. The illness begins with mental disturbance; there are delusions and hallucinations, followed by mania, and the patient may commit suicide or homicide. This stage of excitement lasts for a short time, and is succeeded by a period of depression. The patient becomes sleepy, insensible, and may die in a state of profound apoplexy. Life is, however, often saved by drenching the body with cold water, and applying ice to the head. The over-heated blood is thereby cooled, and the medulla roused from its torpid condition.

The movements of swallowing, which require for their proper execution a co-ordinated action of the lips, tongue, palate, and gullet, are likewise under the immediate influence of the medulla. The same organ contains a centre for the physiognomical play of the muscles of the face, and for articulate speech, that is, the pronunciation of vowels and consonants in such fashion as to form words.

These several facts are well illustrated by the symptoms of a peculiar disease, which, although it has no doubt always existed, has only recently attracted the attention of the medical world, and which consists of wasting of those nerve-cells in the

medulla that preside over the functions just mentioned. This affection, which has received the euphonious name of labio-glosso-pharyngeal paralysis, commences with apparently insignificant symptoms. It is found that speaking, eating, and swallowing require an effort. The tongue feels heavy; the lips do not move properly; the patient experiences difficulty in pronouncing certain letters, such as *b, p, o,* and *u;* he cannot whistle or blow out a candle. As time goes on, the tongue becomes more powerless; more or less of the letters of the alphabet are lost; the soft palate does not act properly, and the voice acquires a nasal twang. The vocal cords become paralysed, the voice is completely lost, and the patient is only able to grunt. He cannot blow his nose, clear his throat, cough, or swallow. In attempting to eat, the tongue fails to form a proper morsel of the food taken, or to push it on to the gullet. The food remains, therefore, between the teeth and the cheeks, and can only be pushed further on to the throat by the aid of the fingers. It is apt to get into the windpipe, and to cause choking. On attempting to drink, the liquid returns through the nose. The unfortunate sufferer thus dies a slow death from starvation, the torments of which can only be inadequately relieved by medical aid. On making a post-mortem examination, wasting of certain nerve-cells in the medulla

is discovered to be the cause of this terrible malady.

All these different functions of the medulla which we have considered, are automatic or mechanical, that is, independent of volition, intelligence, and any other of the higher mental processes. They may, therefore, continue after the higher portions of the brain have been either removed or disorganized by disease.

2. The next great division of the brain which we have to consider consists of the pons and optic lobes, and is the centre for still more complicated actions than those over which the medulla presides. A pigeon from which the higher portions of the brain are removed, but which is left in possession of the meso-cephale and medulla, is still able to respond to a stimulus, but, if left alone, will show complete indifference and loss of initiative. There is no desire, no impulse to any spontaneous action, no recollection of former events. Such an animal will remain day by day, sitting quietly on its feet, without giving any signs of life; and unless artificially fed, will ultimately die of starvation, without feeling the pangs of hunger, and without suffering in any way. As soon, however, as its repose is disturbed, it will give signs of life. If laid on its back, it will struggle until it has regained its previous position on the feet; if pinched, it will walk away; if

thrown into the air, it will flap its wings, and come down to the ground in the ordinary manner. If a light be held to the eyes, the pupils will contract. If ammonia be applied near the nostrils, the animal will draw back with signs of disgust. If a shot be fired near it, it will jump up, and open its eyes; and if food be put into its mouth, it will swallow it.

In frogs and fishes the phenomena are almost identical with those observed in pigeons, being only slightly modified by the different media in which these animals live. In the fish, for instance, the contact with water acts as a constant external stimulus on the mechanism of swimming. A fish from whom the higher portions of the brain have been removed, will therefore not sit still like the pigeon, but will go on swimming until it reaches an impediment to its passage. It follows a headlong and apparently irresistible impulse, yet shows some method, inasmuch as it will avoid obstacles, and turn aside when prevented from going straight on. While a fish in its normal condition will stop on its way, sniff about, pursue a prey, etc., the unbrained fish sails heedlessly along, without ever stopping or taking nourishment, until it dies of exhaustion. In a similar manner an unbrained frog, when thrown into the water, will move on until it reaches *terra firma;* but as soon as it has found a resting-place, will remain in the same state of death-like repose as the

pigeon. In the mammalia the results differ somewhat from those obtained in the lower animals, because the different portions of the brain are in them so intimately connected, and so dependent upon one another, that removal of the higher parts disorders the entire mechanism, and causes such a degree of exhaustion as to interfere greatly with the independent action of the lower centres. Nevertheless, the functions of these latter are identical with those of the same parts in the lower animals; which we conclude from their homologous structure, and also from observations made in disease of these centres.

The expression of the affections, such as fear, terror, pleasure, pain, etc., is likewise under the influence of the second division of the brain. Frogs in which the higher portions of the brain have been removed, will still croak when stroked across the back, and croaking in the frog is the expression of comfort and satisfaction. In ourselves laughing, crying, and other expressions of the affections, are quite involuntary, and independent of reflexion. It is true that we may, by an effort of the will, restrain or inhibit such expressions; but this is done by a special exertion of the inhibitory influence of the higher centres, which comes into play after a long course of training, and is quite absent in children and uneducated persons.

3. The *cerebellum*, or little brain, consists of two

hemispheres, which are situated at the back of the head, beneath the posterior lobes of the brain itself (cerebrum), and intimately connected with the pons and other portions of the central nervous system. This organ was formerly believed to be the seat of the reproductive faculty and desire; but that view has recently been shown to be incorrect. Nor has the cerebellum anything to do with reason, volition, or consciousness; for animals which are deprived of the higher centres, yet left in possession of the cerebellum, do not show any spontaneity of desire or action, and will, for instance, die of starvation with the utmost indifference. If, however, the cerebellum be removed, the animal will move about as if it were drunk; it is not paralysed, and endeavours to carry out certain movements, but there is an utter want of precision, and even the most desperate efforts do not succeed in steadying it. The cerebellum is thus shown to be the organ of equilibration of the body; and this conclusion from physiological experiments has been corroborated by observations of disease of the organ in man. It is likewise known that the different portions of the cerebellum have different parts allotted to them in this respect. One part prevents us from falling forwards; another from falling sideways, and from constantly turning round in a circle; while a third is intended to secure us from falling backwards.

4. The central ganglia, which constitute the fourth great division of the brain, have the function to render certain movements which are intimately connected with sensations, and which are in the first instance only excited by volition and consciousness, gradually, as it were, mechanical and automatic. The object of this contrivance is to save time and trouble to the highest portion of the brain or the grey surface of the hemispheres, which are intended to be habitually occupied only with the most important manifestations of life. The central ganglia may therefore be said to be the confidential servants or private secretaries of the hemispheres, and undertake a good deal of drudgery in order to leave the grey surface at liberty for the finer and more difficult kind of work which falls to our lot in life. Thus we have in childhood and youth to learn the actions of walking, talking, writing, dressing, dancing, riding on horseback, decent eating and drinking, singing, playing on musical instruments, etc., by countless conscious efforts on the part of the hemispheres; and full attention is necessary in the beginning in order to enable us to carry out such movements in a proper manner. But the older we grow, the more frequently we have directed our minds to all forms of action, the less effort will eventually be necessary on the part of consciousness and volition, and ultimately all such movements will be performed mechanically, and with-

out much, if any, attention to them on the part of the grey surface of the brain. A man who is in the habit of writing much, never thinks of the way in which he forms his letters on the paper, over which his pen seems to fly quite mechanically. The same holds good for the various kinds of needlework, embroidery, playing the piano, the violin, etc. If each time we do anything of that sort, a conscious effort were necessary for all the different parts of which the action is composed, the time at our disposal would not suffice for a hundredth part of the work which we actually get through in life; and some forms of activity, such as finished piano and violin playing, would be utterly impossible.

A key is thus afforded for the comprehension of many singular occurrences which would otherwise be quite inexplicable. A pianist, for instance, finds himself playing one of Mozart's sonatas by heart, and is, perhaps, thinking all the time of his coming trip to Switzerland, or something else which may happen to engage his attention; that is, the central ganglia play the sonata, while the hemispheres are busy elsewhere. A very worthy country parson told me some time ago that, when he reads prayers at church, he does it quite as an automaton, for his mind keeps wandering in a totally different direction. A man who knows London well, may walk from his house through a maze of streets with-

the greatest precision to his club, where he arrives without having given the slightest attention, either to the act of walking or the direction he took, but having been in quite another world of thought, all the time he was on his way.

Somnambulism and other automatic conditions, which may occur where there is some disarrangement of the nervous system, may be similarly explained. The lower centres are habitually under the absolute control of the higher ones, that is, the hemispheres; yet this balance of power may be temporarily disturbed by illness or exhaustion of the grey surface, and the central ganglia may then begin to act in their own fashion. What may take place under such circumstances may be aptly compared to certain occurrences which are not uncommon when the family is out of town, and the servants are left in charge of the house. Supposing the hemispheres to have lost their control over the lower centres, elaborate actions may take place which may have all the appearance of deliberate intention, and yet for which the person who commits them can no more be held responsible than the absent master of the house for the misdoings of his servants. The somnambulist who falls from the roof of a house and is killed is no more a suicide than a man who, in the state of epileptic vertigo, commits robbery, arson, and murder can be called a truly responsible

criminal. The legal mind has not yet been able to grasp the full significance of these facts, as shown by conviction to penal servitude of persons who should been sent to hospitals or asylums.

5. The highest development of brain-matter is found in the *hemispheres*, the *convolutions*, or the *grey surface* of the brain, which is the material base of all mental and moral activity. This portion of the brain, which may therefore be called the seat of the soul, is not a single organ, as was formerly supposed, but consists of a number of thoroughly differentiated organs, each one of which has certain functions, and all being in the closest possible connexion with one another by commissural fibres. To define all these various organs with accuracy, to determine their intimate structure as well as their individual energy, and to trace the physiological and pathological alterations which they undergo during the natural processes of development, maturity, and decay, and in diseases to which they are subject, is the greatest problem for the anatomy and physiology of the twentieth century; and when it is solved, a complete revolution in psychology must be the result. At present, however, we are only on the threshold of this enquiry, which is, perhaps, the most difficult and complicated of any which may present themselves to the human mind.

We have already seen that Gall was the first to occupy himself with the localisation of mental faculties in the hemispheres; but he unfortunately soon left the only true road to knowledge, viz., careful examination of the brain after death, and substituted for this an examination of the skull in the living. Phrenology, which at the hands of a great anatomist like Gall, contained a considerable sprinkling of truth in addition to many errors, was soon afterwards taken up by charlatans—persons who had never even seen a brain properly dissected, and who went about the country with casts of skulls of some eminent statesmen, poets, and criminals, and were ready to tell anybody's character from tapping his skull-bones. Such proceedings naturally disgusted scientific men, and the very name of phrenology soon became a byword amongst them. Moreover the minute anatomy of the convolutions of the hemispheres remained in an unsatisfactory state; for progress in this direction was impossible as long as enquirers limited themselves to a study of the adult human brain. It was only when the structure of the brain of monkeys, and the development of the human brain in the various stages of embryonic life was investigated, that a flood of light was thrown on this important subject, and we were taught to distinguish that which is essential from what is accidental.

I cannot attempt, in the limits of the present paper, to enter at all fully into the labyrinth of these convolutions, but must be satisfied with a rapid survey of what is best known with regard to the functions of some of them.

One of the most suggestive results of recent research has been to show that the faculty of intelligent language, as distinguished from simply articulate speech, is situated in the third left frontal convolution and its immediate neighbourhood. We have already seen that the pronunciation of letters and words is effected in the lowest portion of the brain, viz., the medulla (1); but this and all the other inferior organs concerned in speaking, form only, as it were, the instrument on which that small portion of the brain's surface which I have just named is habitually playing. Lower centres are able to hear spoken words, and to see written words; but the intelligent appreciation of the connection which exists between words and ideas, and the faculty of expressing thoughts in sentences—that is, what the Greeks called *logos*—only resides in the third left frontal convolution. This discovery was foreshadowed by Gall, but actually made by Broca, who likewise found that the left hemisphere is altogether more important for intellectual manifestations than the right, and is chiefly trained for talking as well as for most of the finer kinds of work

which we have to perform in daily life. This appears to be owing to the following circumstances: the left hemisphere is originally heavier than the right; the convolutions are more abundantly developed in the left; and, finally, the left is more largely provided with blood than the right, on account of the larger calibre of the bloodvessels which supply it. Most people therefore train chiefly the left hemisphere for the various kinds of work; they are left-brained as they are right-handed. A preponderance of the right over the left hemisphere, on the other hand, seems, according to the most recent researches, to be characteristic of certain forms of insanity.

Physiological experiments on animals point to the third left frontal convolution and its neighbourhood as being concerned in language; for when electricity is applied to it in the living monkey or rabbit, the animal opens its mouth, and alternately protrudes and retracts the tongue. But far more convincing proofs have been given by numerous cases of disease in which there was loss of language during life, and where, after death, a lesion was found limited to the spot just named.

A boy, aged five, who was a great chatterbox, fell out of the window, and injured the left frontal bone, which was found depressed. There was no paralysis, but the boy had entirely lost his language. The

wound healed in twenty-five days; but the child, although intelligent, remained dumb. A year afterwards he was drowned, and at the autopsy it was discovered that the third left frontal convolution had been destroyed by the injury.

A man fell with his horse, but got up, took hold of the reins, and was going to jump into the saddle, when a doctor who happened to be accompanying him expressed the wish to make an examination. It was then found that he could not speak, but had to make himself understood by pantomime. A small wound in the left side of the forehead was found, with depression of bone, but there was no paralysis; inflammation set in, the patient died, and at the post-mortem examination it was found that a fragment of bone had penetrated into the third left frontal convolution, which had become softened.

Talking, writing, drawing, etc., are habitually done by the left hemisphere alone, while both hemispheres have to be trained for musical performances. Pianists educate them both equally, while violinists and cello-players have to train them dissimilarly; and this is probably the reason why it requires more practice and is more difficult to play well on stringed instruments than on the piano.

A man who has, by disease or injury, lost the faculty of talking, is generally also unable to write;

and it is only in exceptional cases that one of these functions persists while the other is in abeyance. Cases of this latter kind show that there are really two separate centres for the two faculties, which are, however, lying very close together, and therefore generally suffer at the same time. If the disease affecting them be still more extensive, the faculty of intelligent pantomime or gesticulation is likewise abolished. Persons who have entirely lost their language may still be able to play chess, backgammon, and whist; and they have been observed to cheat at cards with some ingenuity. They may also be sharp in business matters; facts tending to show that speech and intellect do not run in identical grooves.

Those portions of the hemispheres which correspond in the main to the parietal region, or crown of the head—the parietal lobes—constitute the true motor region of the brain's surface; and as these are in the closest possible connection with that part which is the more immediate base of the intellect and the mind, they have been called the *psycho-motor centres*, in order to distinguish them from the lower motor centres in the central ganglia, the medulla, etc.

The special functions of these psycho-motor centres have been studied by the application of electricity, by destroying them in the living animal,

and also by observation of certain symptoms at the bedside; and it has been shown that each one singly serves some definite purpose, as, for instance, clenching the fist, swimming, grasping, raising the hand to the mouth, etc. Destruction of these centres causes paralysis of such movements, while irritation of them leads to a peculiar form of epilepsy, in which the convulsions affect only one (the opposite) side of the body, and where there is generally no loss of consciousness.

The next great division of the brain's surface is that which corresponds to the temporal region of the skull. These *temporal lobes* of the hemispheres are intended to act as *centres for sensory perceptions.* This is shown by electrifying them in the living animal, and also by localised destruction of the same. One portion of the temporal lobe is the centre of the sense of *hearing.* If this be destroyed in an animal, deafness on the opposite side is the result; on the other hand, if it be electrified, the animal is seen to prick up its ears, and assume the attitude of listening, just as it does when a sudden noise is made close to its ear. In those animals whose habits of life render their safety dependent upon the keenness of their sense of hearing, as, for instance, the wild rabbit and the jackal, galvanization of that part causes not only pricking of the ears and listening, but also a quick jump to the side, as if to

escape from some danger which would be announced by a loud or unusual noise.

The centre for the sense of *smell* is situated close by. If it be electrified, the animal begins to sniff, as if it smelt something strong, just as it does when highly odoriferous substances are placed to its nose. Destruction of this centre causes loss of smell. It is particularly developed in animals which are endowed with a keen sense of smell, such as dogs, cats, and rabbits. A centre for the perception of *taste* is in its immediate neighbourhood. Other portions of the temporal lobe are intended for the sense of *touch*, and the faculty of feeling *pain*; and there is also a *visual* centre, destruction of which causes blindness on the opposite side. All these centres are symmetrically arranged on both sides, the left in the brain serving for the right side of the body, and *vice versâ*.

A third portion of the hemispheres which we have to consider are the *posterior* or *occipital* lobes, which correspond to the back of the head. Their structure differs greatly from that of the parts more in front, and they receive their blood-supply from quite a different set of blood-vessels. Electricity has apparently no influence upon them, and destruction of their substance causes neither paralysis nor loss of sensation. Animals from whom these lobes have been removed, continue to see, hear,

touch, taste, and smell, and move about just as usual; they generally, however, refuse to eat, and succumb rapidly. We are inclined to look upon these lobes as specially connected with the digestive tract, more especially the stomach and liver, and also with the reproductive organs; yet the symptoms of disease of these lobes are contradictory and perplexing, and our knowledge concerning them is, as yet, in its infancy.

The last, and most important portion of the hemispheres—if we can speak of degrees where everything is important—are the *anterior* or *frontal lobes*, which correspond to the forehead. These are the actual seat of the intellect. Injury or disease of those lobes does not cause any impairment of motion or sensation, and large portions of brain-matter have occasionally been lost through wounds in these parts without any very striking symptoms, such as paralysis, etc., following, more especially where the lesion was confined to one side. Patients have now and then recovered from the most fearful injuries to these parts, and yet be able to go about and attend to the ordinary routine of certain occupations; but it has always been shown on close examination that there has been a profound change in the character and behaviour of such persons, and that their temper and their mental and moral faculties had become deteriorated. In a very marked case of this kind,

which occurred in a previously steady and clever workman, there was, after recovery from the injury, such a change in the mind of the man, that his employers had to discharge him. The balance between his intellectual faculties and his animal propensities had evidently been destroyed. He had become capricious and vacillating, fitful, impatient, obstinate, and, as far as intellectual capacity was concerned, appeared to be a child, who, however, had the animal passions of a strong man. In consonance with such cases is Ferrier's experience with monkeys, in whom he had destroyed these lobes. The animals did not appear to have lost the power of motion or sensation, yet there was an alteration in their character. While previous to the operation they were actively interested in their surroundings, and pried into everything which came within their sphere of observation, they had after it become dull and apathetic, readily dosed off to sleep, or wandered to and fro in a listless manner; so that it was evident that they had lost the faculty of attentive and intelligent observation.

The anterior lobes have, therefore, to be looked upon as the organic base of the higher intellectual and moral faculties. The principal part of the work done in life consists of certain movements or actions which are the more or less direct consequence of sensations and desires which we experience; but

apart from the power of performing such actions, we have the faculty of restraining or inhibiting them, in spite of being urged to their performance by sensations or desires. This inhibitory action is again most intimately connected with the power of concentrating attention and consciousness, without which none of the higher intellectual operations are possible. The anterior lobes are therefore inhibitory centres, intended for the highest kind of mental work and moral control. They are small in idiots and in the lower animals, larger in monkeys, and largest in man; and their peculiarly large and abundant development coincides with a particularly high development of intellectual power. It is probable that a special evolution of certain parts of these lobes will be found to coincide with the presence of certain special aptitudes and talents in individuals; but of this nothing definite is known, and there is in this direction an immense field still open for patient and intelligent enquiry.